Northeast Fisheries Science Center Reference Document 11-03

Preliminary Summer 2010 Regional Abundance Estimate of Loggerhead Turtles (*Caretta caretta*) in Northwestern Atlantic Ocean Continental Shelf Waters

by the Northeast Fisheries Science Center
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Editorial Treatment: To distribute this report quickly, it has not undergone the normal technical and copy editing by the Northeast Fisheries Science Center's (NEFSC's) Editorial Office as have most other issues in the NOAA Technical Memorandum NMFS-NE series. Other than the four covers and first two preliminary pages, all writing and editing have been performed by the authors listed within. This report was reviewed by the Stock Assessment Review Committee, a panel of assessment experts from the Center for Independent Experts (CIE), University of Miami.

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SUMMARY

The Northeast and Southeast Fisheries Science Centers estimated the 2010 abundance of juvenile and adult loggerhead turtles (*Caretta caretta*) in the portion of the northwestern Atlantic continental shelf between Cape Canaveral, FL USA and the mouth of the Gulf of St. Lawrence, Canada based on data collected from an aerial line-transect sighting survey and satellite tagged loggerheads. The preliminary regional abundance estimate, accounting for perception and availability bias, was about 588,000 individuals (approximate inter-quartile range of 382,000–817,000) based on only the positively identified loggerhead sightings, and about 801,000 individuals (approximate inter-quartile range of 521,000–1,111,000) when based on the positively identified loggerheads and a portion of the unidentified turtle sightings.

During the aerial survey, 598 detected groups were positively identified as loggerheads and 457 groups were classified as unidentified hardshell turtles. Using line-transect analytic methods, the preliminary surface abundance, accounting only for perception bias, ranged from about 60,000 (CV=0.13) individuals when based on only positively identified loggerheads to about 85,000 (CV=0.10) individuals when based on the positively identified loggerheads and a portion of the unidentified turtles.

To account for availability bias, the percentage of time loggerheads were available to be seen by the aerial observers was defined as the percent of time loggerheads were within the top 2 m of the water column. This was estimated using time and depth specific data collected from 44 juvenile loggerheads equipped with satellite tags in the south (between northern Florida to South Carolina) and in the north (between New Jersey to Delaware). In general, tagged loggerheads spent more time at the surface when in the north than in the south. For this preliminary abundance estimate, it was assumed the most appropriate percent dive time was calculated from the daytime (8am – 8pm) during the days when the plane was in the same strata as the tagged loggerheads. Thus, the estimated preliminary median percent surface time was about 7% (inter-quartile range of 5–11%) for loggerheads south of Cape Hatteras, NC, and about 67% (inter-quartile range of 57–77%) for those north of Cape Hatteras, NC.

The estimates presented in this manuscript are considered preliminary. Subsequent analyses to improve the estimate include: estimating the percent surface time and its variance using repeated measure statistical methods to include individual effects on the repeated measures to properly estimate the variability; collecting additional data on surface times and more fully exploring the available surface time data to determine the most appropriate measures of percent surface time for regions within the study area; improving the analysis of availability bias by incorporating the time between detections of duplicate sightings and the average times the loggerheads spent at the surface; investigating the sizes of loggerheads and depths to which they can be detected from the survey plane; and investigating the spatial and temporal variability in the estimates.

INTRODUCTION

The Northeast Fisheries Science Center (NEFSC) and Southeast Fisheries Science Center (SEFSC) of NOAA Fisheries Service conducted line-transect aerial abundance surveys and turtle telemetry studies to estimate the abundance of cetaceans and sea turtles in the northwestern Atlantic continental shelf during the summer of 2010, The east-west extent of the northwest Atlantic continental shelf study area was from the coast to the 200 m depth contour when south of 40˚N and from the coast to the 2000 m depth contour when north of 40˚N. The north-south extent of the study area was from Cape Canaveral, Florida to the mouth of the Gulf of St. Lawrence, Canada. This work is part of the AMAPPS (Atlantic Marine Assessment Program for Protected Species) project, which is a large, multi-agency initiative to provide a comprehensive assessment of marine mammal, sea turtle and seabird abundance and spatial distribution in U.S. waters of the western North Atlantic Ocean. The partners of AMAPPS are NOAA Fisheries Service, US Fish and Wildlife Service (USFWS), Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE), and the US Navy.

To achieve the AMAPPS objectives, NOAA needs to provide accurate, unbiased data on marine mammals, sea turtles and sea birds. This requires that both perception and availability bias are accounted for, whenever possible. Perception bias is caused by animals being missed, particularly on the track line, even though they are available to be detected. This might be due to poor sighting conditions. Availability bias is caused by animals being missed because they are not available to be detected. This might be due to animals diving so far below the surface they are not detected by an observer.

Two general procedures can be used to account for these biases (Laake and Borchers 2004); this study utilized both procedures. The first procedure involves two steps where one step is to collect line transect data from two observation teams to account for perception bias. The second step, which is independent of the line transect survey, is to collect behavioral measurements, such as dive times, to estimate the probability animals are available to the line transect survey observers; this addresses availability bias. This is the only procedure that can account for availability bias of long-diving species such as loggerhead turtles (*Caretta caretta*). This procedure was used for loggerheads in Spanish Mediterranean waters (de Segura *et al.* 2006).

The second procedure can simultaneously account for both perception and availability bias, but only for short-diving species. This involves collecting line transect data following the "circle-back method", which is a procedure involving two observation teams on separate platforms (Hiby 1999; Laake and Borchers 2004). The amount of separation needed to account for availability bias is dependent on the dive duration (Hiby and Lovell 1998); the longer the dive time the further the separation between the two platforms. Consequently, if there is only a short time separation between survey platforms, availability bias will not be fully accounted for with long-diving species. In this situation, only perception bias can be accounted for. This procedure was used by Scheidat *et al.* (2008) who used the circle-back method to estimate the abundance of harbor porpoises (*Phocoena phocoena*) in the southwestern Baltic Sea.

This manuscript focuses on providing a preliminary estimate of the abundance of larger juvenile and adult loggerheads in a portion of the waters of the northwestern Atlantic continental shelf using aerial line-transect sightings data and telemetry data that were collected during field studies conducted in May – Sep 2010. The resulting loggerhead abundance estimate is considered preliminary and will be followed by a subsequent more thorough analysis.

MATERIAL AND METHODS

The northwestern Atlantic continental shelf study area was divided into four spatial strata (Figure 1) that represent different loggerhead habitats:

- *South Atlantic*: a southernmost stratum ranging from Cape Canaveral, Florida to Cape Hatteras, North Carolina (about 28˚N – 35˚N latitude) and from the shore to the 200 m depth contour,
- *Mid-Atlantic South*: a southern mid-Atlantic stratum ranging from Cape Hatteras, North Carolina to New Jersey (about 35˚N – 40˚N latitude) and from the shore to the 200 m depth contour,
- *Mid-Atlantic North*: a northern mid-Atlantic stratum ranging from New Jersey to Massachusetts (about 40˚N – 42˚N latitude) and from the shore to the 2000 m depth contour, and
- *North Atlantic*: a northernmost stratum ranging from Massachusetts to the mouth of the Gulf of St. Lawrence, Canada (about 42˚N – 45˚N latitude) and from the shore to the 2000 m depth contour.

To achieve the AMAPPS objectives, the most appropriate data collection and analysis methods varied between the strata, because the strata provide proxies for different species compositions, dive time patterns, and density levels. In the northern two strata (North Atlantic and Mid-Atlantic North), it was expected there would be relatively high densities of many short-diving species of small cetaceans and low densities of long-diving turtles. In the southern two strata (South Atlantic and Mid-Atlantic South), it was expected there would be mostly long-diving turtles and short-diving bottlenose dolphins, and only a few other cetacean species.

To provide data necessary to account for perception and availability biases in the loggerheads abundance estimate, the two-step procedure was used: 1) a two-team aerial line-transect survey was conducted to estimate the surface abundance of loggerheads, and 2) dive times from tagged loggerheads were used to estimate the percent of surface time.

Two forms of the two-team aerial survey were implemented. The first was the circle-back aerial line-transect method (Hiby and Lovell 1998; Hiby 1999) which was used in the two northern strata where large numbers of short-diving cetaceans were expected. This is a modification of the two separate platform procedure, and was originally designed to estimate both perception and availability bias for short-diving cetaceans that are found in small groups and are not clustered in large aggregations. One example of this situation is harbor porpoises whose average dive time is 3–4 minutes (Hiby and Lovell 1998; Hiby 1999). However, because loggerhead's average dive time is much longer, the circle-back method as executed in this survey was only able to account for perception bias for loggerheads. For example, dive times are about 14–30 minutes for adult female loggerheads during the summer nesting season and up to an hour or more for neritic juveniles in the northwestern Atlantic during the summer (Byles 1988; Mansfield 2006; Sakamoto *et al.* 1990a; 1990b;).

In the two southern strata, where high densities of long-diving turtles were expected, the circle-back method was not appropriate and the two-simultaneously surveying team procedure was deemed the most appropriate method; thus allowing estimation of only perception bias of all detected species (Laake and Borchers, 2004).

Availability bias for loggerheads was dealt with using telemetry data. The 2010 telemetry study was initiated in two general locations because dive time patterns, and thus the percent surface times, were expected to be different in different parts of the loggerheads' habitat. Detailed field methods and analytical methods for the aerial survey and tagging studies are described below.

Field Methods

Aerial abundance survey

The 2010 aerial abundance line transect surveys covered the four strata within the northwestern Atlantic continental shelf study area using a chartered DeHavilland Twin Otter DHC-6 during 24 Jul – 24 Sep 2010 (Figure 1). The survey was conducted along tracklines oriented either perpendicular to the coast or at an angle aligned to cut across the expected spatial onshore-offshore animal density gradient. The survey was flown at an altitude of 183 m (600 ft) above the water surface and at a speed of approximately 200 kph (110 kts). The survey was typically flown only when surface wind speeds were less than 20 kts or approximately sea state 4 or less on the Beaufort scale.

Data were recorded onto a laptop computer running data acquisition software that recorded GPS location, environmental conditions entered by the observer team, effort and sighting information, and surface water temperature. Surface water temperature was measured by an infra-red temperature probe deployed in a port just forward of the belly window.

During on-effort periods (e.g., level flight at survey altitude and speed) in all strata, observers visually searched from the trackline, from straight down (0˚) to approximately 50˚ or 60˚ above vertical. When a turtle, marine mammal, or other organism was observed, the observer waited until the organism was perpendicular to the plane and then measured the angle to it (or the center of the group) using a digital inclinometer or, based upon markings on the windows, recorded the angle to either the nearest degree or in 10˚ intervals. The belly observer in the two southern strata only reported the interval to the location of the sighting. Fish species were recorded opportunistically. Species identifications were recorded only when the observers were certain of the identification; otherwise, the group was identified to the lowest taxonomic level possible (e.g. "fin or sei whale", or "unidentified turtle").

The differences due to the circle-back and two-simultaneous team procedures used in the northern and southern strata, respectively, were mainly reflected in the definition of the "two teams". The two-simultaneous team procedure used in the two southern strata involved six scientists onboard the plane that operated as two independent teams, where each team consisted of three scientists. The forward team of three scientists included two observers looking through bubble windows on either side of the plane and a dedicated data recorder collecting data from only the forward team. The bubble windows allowed downward visibility including the trackline. The aft team of three scientists included one observer looking straight down through a belly window, a second observer looking through a large side window, and a dedicated data recorder collecting data from only the aft team. For the aft team, the side observer did not have complete visibility of the trackline, and the belly observer had visibility of only approximately 30˚ on either side of the trackline. The aft team side window observer alternated sides of the aircraft each day. The two observer teams operated on independent intercom channels, and were not able to cue one another to sightings.

The circle-back procedure used in the two northern strata was conducted by one team of five scientists who acted as two teams whose sightings were separated by several minutes (the time to circle back and possibly re-locate the sighting). The team consisted of three scientists searching through two bubble windows and a belly window, a data recorder, and one scientist who was at rest (and so did not contribute sightings). The way this group of observers acted as two teams is, first "team 1" was on-effort searching for groups of animals, then after a small group of animals with ≤ 5 animals was detected by "team 1", the plane followed a standardized procedure resulting in it leaving the track line and circling back to a position on the track line before the location of the detected animals, thus allowing the track line to be surveyed a second time by the same observers who were now acting as "team 2". The re-surveyed portions of the track lines were called "trailing" legs, the track line portions that initiated a circle were called "leading" legs, while the track lines between the circles were called "single-plane" legs. The circle-back procedure is detailed in Appendix 1.

In both procedures perception bias [*g(0)*] was estimated using the data collected from both teams, where some animal groups were detected by only one team and other groups were detected by both teams (termed a duplicate sighting). After the survey, the data were reviewed to identify duplicate sightings based upon time, location and position relative to the trackline.

In both procedures, search effort was stopped if the plane needed to circle a group to verify species identification and group sizes, and to take photographs. Because of the different definitions of teams, the break-off procedures were slightly different.

In the case of the two-simultaneous team procedure, turtle sightings were recorded independently by each team, without communication between the teams on the plane. For marine mammal sightings, if the sighting was made initially by the forward team, they waited until the sighting was aft of the plane to allow the aft team an opportunity to detect the sighting. Once both teams had the opportunity to observe the sighting, observers asked the pilots to break effort and circle the sighting. The plane circled over the majority of the marine mammal groups sighted to verify the id.

In the case of the circle-back procedure, the plane could break to verify the species identification if a group triggered the circle-back procedure and was still unidentified on the trailing leg, or if a group that did not trigger the circle-back procedure was unidentified. In both of these cases, about 10 seconds after the unidentified group was detected on either the trailing or single-plane leg, the observers could ask the pilots to break effort and circle the sighting to verify the species identification and group size.

Telemetry study

The 2010 tagging study was initiated in two general locations because dive time patterns, and thus the percent surface time, was expected to be different in different parts of the loggerheads' habitat. During 24 May – 14 Jul 2010, SEFSC scientists, in collaboration with the South Carolina Department of Natural Resources, deployed 30 Wildlife Computers MK-10 satellite tags on juvenile loggerheads off the coasts of northern Florida to South Carolina, within the South Atlantic stratum (referred to as the southern tagged turtles). During 4 Aug – 11 Sep 2010, NEFSC scientists partnered with Coonamessett Farm Foundation, with the assistance of Viking Village Fisheries and the *F/V Kathy Ann*, to deploy 14 Sea Mammal Research Unit's (SMRU) Fastloc GPS satellite relay data loggers (SRDLs) on juvenile loggerheads that were 50–100 miles offshore the New Jersey and Delaware coasts, within the Mid-Atlantic South stratum (referred to as the northern tagged turtles).

In both tagging locations, loggerheads were captured in-water (via dipnets in the north and trawls in the south), and epoxy was used to attach the tag to the first and second central carapace scutes using methods described in Mansfield *et al.* (2009) and Seney and Landry (2008). Captured loggerheads were also measured, photographed, biopsied and tagged with flipper and PIT tags.

Both tag type's archive information in their memory and then relay an unbiased sample of detailed individual dive records and summary records to overhead satellites. The southern Wildlife Computers MK-10 satellite tags programmed with a 24 hr on and 72 hr off duty cycle. Fourteen time-at-depth bins (0 [wet and dry], >0–1 m, >1–2 m, >2–3 m, >3–4 m, >4–5 m, >5–10 m, >10–20 m, >20–30 m, >30–40 m, >40–50 m, >50–100 m, >100–150 m, and >150 m) and fourteen time-at-temperature bins were programmed (in 2˚C intervals within the range 8˚–32˚C and >32˚C). Time information was also summarized in 4-hr periods: 8 am – 12 pm, 12 pm – 4 pm, 4 pm – 8 pm, 8 pm – 12 am, 12 am – 4 am, and 4 am – 8am.

The northern SRDL tags have a transmission target of 70,000 Argos transmissions. For the first four months of deployment a Fastloc GPS was enabled. For the first two months (Aug – Sep 2010 which was during the aerial abundance survey) the tags were programmed to collect highly detailed information and were not duty-cycled. To collect the detailed information the SRDL tags checked temperature (not used in this context) and pressure (0.5 m depth resolution) sensors every four seconds. Time and depth information was recorded in 6-hr summary periods: 8 am – 2 pm, 2 pm – 8 pm, 8 pm – 2 am, and 2 am – 8 am. Depth usage patterns were recorded as the proportion of each 6-hr summary period spent in each of the following pre-defined depth bins: dry, 0 (wet)–<1 m, 1–<2 m, 2–<3 m, 3–<4 m, 4–<5 m, and ≥5 m.

Analytical Methods

Within stratum a, the abundance of juvenile and adult loggerheads accounting for perception and availability bias (N_a) was estimated from two quantities $N_a = N_{Sa}/\%s_a$. The first quantity was the stratum abundance, accounting for perception bias, of loggerheads at or near the water's surface (surface abundance, N_{Sa}). This was calculated using line-transect methods. The second quantity, which accounts for availability bias, was the percentage of time loggerheads within stratum a spent in the portion of the water column where they could be detected by aerial observers (percent surface time, $\%s_a$). This was calculated using dive time data collected from tagged loggerheads. The total 2010 regional abundance of juvenile and adult loggerheads within the study area was the sum of N_a from all four strata.

Surface abundance

The preliminary regional surface abundance estimate of loggerheads that accounts for perception bias utilized data from both the positively identified loggerheads sightings and the unidentified hardshell turtle sightings (that is excluding leatherback turtles, *Dermochelys coriacea*). Because several species of turtles were positively identified within a stratum and there appeared to be strong geographic differences in the proportion of other turtle species, it was assumed that only a portion of unidentified turtles were loggerheads, and this proportion was stratum specific. Thus the best estimate of the surface abundance of loggerheads (N_{sL+}) within a stratum was estimated as:

$$N_{sL+} = N_{sL} + \left[N_{sU} \times \frac{n_L}{n_T}\right] \tag{1}$$

where

N_{sL} = surface abundance of only positively identified loggerheads
N_{sU} = surface abundance of only unidentified hardshell turtles
n_L = number of positively identified loggerhead groups
n_T = total number of all positively identified turtle groups

The estimation of the surface abundance when using both the two-simultaneous team or circle-back procedures is based on the independent observer approach assuming point independence (Laake and Borchers 2004) and calculated using the computer program Distance (version 6.0, release 2, Thomas *et al.* 2009). Because of the differences in the data collection procedure, they were implemented differently.

For the South Atlantic and Mid-Atlantic South strata where the two-simultaneous team procedure was used, the analysis method used is considered an extension of the standard line-transect distance analysis such that the direct estimation of the sighting probability on the trackline implicitly includes the estimation of *g(0)* and is based on the abundance of groups and the average size of those groups. The probability of sighting a particular group is the product of two probability components. The first probability component corresponds to the "standard" sighting function, such that the probability of detection declines with increasing distance from the trackline following a known functional form (typically the half-normal or hazard function). The second probability component is the likelihood of detection on the trackline, which was modeled using a logistic regression approach and the "capture histories" of each sighting (i.e., seen by one or both teams). The logistic model could include covariates that affect the probability of detection such as viewing or weather conditions. Details on the derivation, assumptions, and implementation of this estimation approach are provided in Laake and Borchers (2004).

For the North Atlantic and Mid-Atlantic North strata where the circle-back procedure was used, the surface abundance of positively identified loggerheads, N_{sL}, was the product of two components. The first component corresponded to the "standard" surface abundance, not accounting for perception bias, that is, uncorrected for *g(0)*, $N_{SL \cdot unc}$ which was estimated using the 2010 data from the single-plane and leading legs (*i.e.*, corresponding to a conventional single-plane single-team line transect survey) and is based on the abundance of groups and the average size of the groups. This was implemented in the Distance computer program, where covariates were used to estimate the probability of detection which declined with increasing distance from the trackline, otherwise known as the effective half-strip width, *ESW*. The second component was the probability of detecting a group on the leading leg track line, *g(0)*, for loggerhead groups of size five or less: $g(0)_{leading} = n_{dup} \cdot ESW_{trailing} / n_{\cdot trailing} \cdot ESW_{dup}$. All loggerhead groups were of size ≤ 5. The second component was derived from loggerhead sighting data collected by the "two separate teams" when assuming point independence (Palka 2005) and implemented in the Distance computer program where covariates were used to separately estimate the probabilities of detections for the trailing and duplicate sightings, $ESW_{trailing}$ and ESW_{dup}, respectively. To increase the sample size and therefore obtain a more precise estimate of $g(0)_{leading}$ the loggerhead data from the leading and trailing legs were pool over the 2004, 2006, 2007, 2008, and 2010 aerial surveys, where each year's data were collected using the same field data collection methods as described above; also year was included as a potential covariate. Thus, the surface abundance accounting for perception bias when using the circle-back procedure was defined as $N_{sL} = N_{SL \cdot unc} / g(0)_{leading}$. Because there were so few unidentified turtles detected in the two northern strata, to estimate the surface abundance estimate of unidentified turtles (N_{sU}), the ESW and $g(0)_{leading}$ estimates of positively identified loggerheads had to be used, along with the number of unidentified turtles, so $N_{sU} = N_{SU \cdot unc} / g(0)_{leading}$.

For both data collection procedures, detection probabilities were estimated using the computer program Distance (Version 6), where perpendicular distances were right truncated following guidance in Buckland *et al.* (2001) thus accounting for differences in observers, their searching behavior and surveying conditions, etc. The form of the detection function (hazard versus half-normal) and the inclusion of covariates in the various components of the model were evaluated through model selection based upon the Akaike Information Criterion (AIC) following guidelines in Marques and Buckland (2003). Covariates investigated in the analyses of both procedures included the distance from the trackline, sea state and glare; those investigated only in the south were turbidity, and sun penetration; and those investigated only in the north were percent cloud cover, subjective quality of the sighting conditions, time of day the sighting was detected, and survey year. Group size was not included as a possible covariate because the groups were nearly always of size 1 and no more than 2–3 turtles in close proximity to each another.

The coefficient of variation (CV) of the surface abundances were estimated using the delta method (Buckland et al. 2004).

Percent surface time

Using the ARGOS satellite data processing system, all location data derived from the southern tags were archived and filtered based on accuracy of transmission ARGOS indexes accuracy using Location Codes 3-0, A and B ranked in order of declining location accuracy (CLS 2007). Data were also filtered based on turtle behavior (reasonable swim speeds and distances between locations), and tracks were reconstructed using the Satellite Tracking and Analysis Tool (STAT; Coyne and Godley 2005).

Preliminary estimates of percent surface time ($\%s_a$) were derived from time and depth specific telemetry data. It was assumed that a loggerhead was able to be detected from the survey plane when the animal was within the top 2 m of the water column. The time spent within the top 2 m was calculated as the sum of times when the tag was on the surface (when dry or wet), and when it was between the surface and 2 m deep. Because the aerial surveys were only flown during daylight, only the data representing dive patterns from 8 am – 8 pm (local standard time) were used. To eliminate any false dive time patterns that might have occurred due to the tagging process, dive time data recorded within the first 24 hrs after tagging were not used. Because dive patterns are due to a variety of factors, including time of year and location, preliminary percent surface times for a stratum were calculated using data collected during times the plane was surveying the stratum.

Preliminary percent surface times of loggerheads in the three northerly strata were calculated from northern tagged loggerheads that were recorded during 7–11 Aug 2010 (when the plane was surveying the Mid-Atlantic South stratum). The calculation used data from two of the 6-hr summary periods (8 am–2 pm and 2 pm–8 pm) and the percent of time spent in the three depth bins representing the top 2 m of the water column (0 (dry), 0 (wet)–<1 m and 1–<2 m).

Preliminary percent surface times of loggerheads in the South Atlantic stratum were calculated from southern tagged loggerheads that were recorded during 24 Jul – 4 Aug 2010 (when the plane was surveying the South Atlantic stratum). In this stratum, data were used from three of the 4-hr summary periods (8 am – 12 pm, 12 pm – 4 pm and 4 pm – 8 pm) and the percent of time spent in the three depth bins representing the top 2 m of the water column (0 (wet and dry), >0–1 m and >1–2 m).

The median percent surface time was considered to be the most appropriate preliminary measure of central tendency because the distributions of surface time were asymmetric. A simple coefficient of variation (CV) of the percent surface time was considered to be an inappropriate estimate of the true CV of the percent surface time because the tagged data consist of the same measurements taken multiple times from a limited number of loggerheads and the effects of the individuals were not accounted for in this preliminary analysis. However, the inter-quartile values (25% and 75% quartiles) were reported to provide a general indication of the variability around the percent surface time.

The CVs for total abundance (product of the surface abundance and inverse percent surface time) are also not reported here. Only the inter-quartile values were reported to provide a general indication of the variability. The lower (upper) inter-quartile value of the total abundance was estimated as the product of the point estimate of surface abundance and the inverse of the upper (lower) inter-quartile value of the percent surface time.

RESULTS

Preliminary Surface Abundance Estimates

During 24 Jul – 26 Sep 2010 the aerial survey covered the four strata within the northwestern Atlantic continental shelf study area (491,641 km^2) with 17,142 km of on-effort track lines (Table 1; Figure 1). Most of the survey was conducted in sea state conditions of Beaufort 4 or less. During the survey, 1310 sea turtle groups from four species were detected, of which 598 groups were positively identified as loggerheads and 457 groups were classified as unidentified hardshell turtles (Table 2; Figures 2–4).

Most of the loggerheads were detected in the South Atlantic stratum, and the number of observed groups decreased as the survey progressed northward. No loggerheads were detected in the North Atlantic stratum (Figure 2).

A portion of the sightings recorded as unidentified hardshell turtles (Figure 3) were assumed to have actually been loggerheads. Using numbers of positively identified turtles within a stratum, it was assumed that of the sightings recorded as an identified hardshell turtle, 68% (34/50), 66% (183/277) and 92% (381/413) were loggerheads within the Mid-Atlantic North, Mid-Atlantic South, and South Atlantic strata, respectively. These percentages were used to assign a proportion of the abundance estimate of unidentified hardshell turtles to be part of the total abundance estimate of loggerheads.

For the abundance estimate of positively identified loggerheads (N_{sL}) in the Mid-Atlantic North stratum, the *ESW* from the single and leading legs was 210 m (CV=0.15) which was derived from a detection function with sight time as the only significant covariate, and a truncation distance of 450 m (Table 3A). All groups seen in this stratum were single animals. The estimate of *g(0)* was 0.70 (CV=0.34) (Table 3B), where the detection function of the duplicate sightings ($ESW_{L\cdot dup}$) was modeled with sea state as the only significant covariate and the detection function of the trailing sightings ($ESW_{L\cdot trailing}$) was modeled with three covariates: sea state, percent cloud coverage, and sighting time. Thus, the resulting surface abundance, accounting for perception bias, for positively identified loggerheads was 3,873 (CV=0.544) individuals in the Mid-Atlantic North stratum and zero in the North Atlantic stratum (Table 3A).

Because there were only seven unidentified turtle groups in the Mid-Atlantic North stratum and none in the North Atlantic strata, the estimates of *ESW* and *g(0)* for the unidentified turtle abundance estimate was assumed to be the same as that for positively identified loggerheads. As a result, the estimated surface abundance estimate, accounting for perception bias, for unidentified turtles was 906 (CV=0.581) individuals in the Mid-Atlantic North stratum and zero in the North Atlantic stratum (Table 3A).

For the two southern strata, a total of 555 positively identified loggerhead groups were included in the analysis after truncation to 300 m, where the average group size was 1.3. Of these groups, 221 were seen only by the forward team, 146 only by the aft team, and 188 by both teams. The half-normal function for the sighting function was preferred over the hazard rate or other alternative models. Model selection based upon the minimum AIC indicated that a model including distance from the trackline, sea state, and glare was the preferred model for the logistic detection function. The resulting model estimated an average sighting probability of 0.447 (CV=0.052) corresponding to an average *ESW* that implicitly includes an estimate of *g(0)* of 134 m (Table 4). The resulting surface abundance of positively identified loggerheads was 38,974 (CV=0.164) individuals for the South Atlantic stratum, and 17,376 (CV=0.197) individuals for the Mid-Atlantic South stratum (Table 4).

For the two southern strata, a total of 429 unidentified hardshell turtle groups were included after truncation, where the average group size was about 1.2. Of these, 199 were seen by the forward team only, 121 by the aft team only, and 109 by both teams. As with the positively identified loggerheads, a half-normal detection function was selected for the sighting function and a model with distance from the trackline, sea state, and glare was selected for the logistic detection function. The resulting model estimated an average detection probability of 0.57 (CV=0.087) in the surveyed strip corresponding to an average *ESW* of 172 m. The resulting surface abundance of unidentified hardshell turtles was 14,825 (CV=0.193) individuals for the South Atlantic stratum and 16,379 (CV=0.192) individuals for the Mid-Atlantic South stratum (Table 4).

The total surface abundance estimate, accounting for perception bias, within the entire study area was 60,223 (CV=0.126) individuals when based on only positively identified loggerheads, and 85,335 (CV=0.102) individuals when based on positively identified loggerheads and a portion of the unidentified hardshell turtles (Table 5).

Preliminary Percent Surface Estimates

During 4 Aug – 11 Sep 2010, the 14 juvenile loggerheads that were satellite-tagged offshore of New Jersey and Delaware ranged from about 61–97 cm curved carapace length (CCL) which is about 57–90 cm straight carapace length (SCL) (Table 6). During 24 May – 14 Jul 2010, the 30 juvenile loggerheads tagged offshore of northern part of Florida to South Carolina ranged from 63–86 CCL or 58–80 cm SCL (Table 7). Daily location data are accessible at http://www.seaturtle.org/. From their initial capture locations off New Jersey and Delaware, the northern tagged loggerheads moved south along the continental shelf and were off of North Carolina by 1 Dec 2010 (Figure 5). In general, these tagged loggerheads spent less time at the surface as they moved south in the early autumn (Figure 6). Thus, changes in surfacing behavior are potentially confounded by the spatial and temporal changes in the locations of the tagged turtles.

With the exception of one animal, most of the southern loggerheads tagged in the South Atlantic stratum remained within close or regional proximity (approximately <100–300 km) to their capture location (Figure 7). All remained on the continental shelf within near-shore coastal waters for the duration of their transmission period. One loggerhead immediately traveled north to Maryland's waters of the Chesapeake Bay, where it remained until its tag ceased transmitting in late August 2010. This individual was not used in the calculation of the percent surface time.

The median percent surface time during the Mid-Atlantic South stratum aerial survey time period (7–11 Aug 2010) was 67%, with an inter-quartile range of 57–77%. This percent surface time was applied to the surface abundance estimate for the loggerheads within the North Atlantic, Mid-Atlantic North and Mid-Atlantic South strata (Tables 8 and 9). The median percent surface time during the South Atlantic stratum aerial survey time period (24 Jul – 4 Aug 2010) was 7%, with an inter-quartile range of 5–11%.

Preliminary Regional Abundance Estimate

The preliminary regional abundance estimate of positively identified loggerheads in all strata within the northwestern Atlantic continental shelf study area, accounting for perception and availability bias, is about 588,000 with an inter-quartile range of about 382,000–817,000 (Table 8). When an appropriate proportion of unidentified turtles were also included, the preliminary regional abundance estimate increased to about 801,000 with an inter-quartile range of about 521,000–1,111,000 (Table 9).

DISCUSSION

The presented regional abundance estimate is considered preliminary, which will be followed by a subsequent, more thorough analysis. The issues and future analyses are discussed below.

Surface Abundance Estimates

The surface abundance estimate presented in this paper assumed that from 183 m (600 ft) altitude aerial observers were able to detect all of the sizes of juvenile and adult loggerheads that can be found within the study area, were able to see them down to about 2 m depth, and were able to identify the species correctly. Epperly et al. (1995a) conducted an experiment to determine whether animals of various sizes could be sighted from an altitude of 152 m (500 ft) and concluded that animals 30 cm or larger should be detectable. Thirty cm is smaller than the minimum size at which oceanic stage loggerheads transition into the neritic study area waters (TEWG 2009). In 2009 another experiment was conducted at 183 m (600 ft) and those preliminary analyses are consistent with the Epperly et al. (1995a) findings. There have not been any formal experiments that investigate the depth to which a loggerhead can be detected or what the mis-identification rate is, especially for small sized turtles. Thus, it is recommended that more experiments be conducted to determine the approximate depth at which loggerheads can be detected and possibly to estimate the species mis-identification rate. It might be possible to improve the species identification process during the abundance surveys by photographing nearly all turtle sightings. If the photographs were calibrated it might also be possible to more accurately determine the sizes of detected loggerheads.

Additional covariates could influence the detection rate. It has already been shown that loggerhead density is influenced by factors such as water temperature (either surface or at the bottom) and bottom depth (Byles 1988; Epperly et al. 1995b; Keinath 19993; Mansfield 2006).

Thus, including these variables into a spatially explicit abundance estimate could result in a more accurate and/or precise abundance estimate.

Percent Surface Time Estimates

The loggerhead telemetry data require further analyses to determine the most appropriate estimate of the percent surface time and its variability. This is important to do because the percent surface time estimates have the potential to influence the surface abundance estimate by at least an order of magnitude, especially in the South Atlantic stratum where there were many surface loggerheads and the estimated percent surface time was very short.

When estimating the percent surface time it is important to account for the fact that the telemetry data are repeated measures taken from a limited number of individuals. Thus, mixed models (or other similar statistical methods) should be used to account for the effects of individuals. Ignoring this issue deflates the measures of variability, and may even affect the point estimate. Thus, CV estimates derived from standard methods were not presented for the present preliminary percent surface time estimates and total abundance estimate.

Percent surface estimates for the North Atlantic and Mid-Atlantic North strata were assumed to have been the same as that derived from data from the Mid-Atlantic South strata. However, because none of the tagged loggerheads actually entered the North Atlantic or Mid-Atlantic North strata, it is recommended that loggerheads be tagged in these strata so that this assumption can be validated.

Telemetry data from an entire stratum that was contemporary with the aerial surveys was used to estimate surfacing time. Though this is an appropriate preliminary assumption, each stratum is very large and, especially for the Mid-Atlantic South stratum, there appears to be a large gradient, which makes it difficult to determine the most appropriate percent surface time to apply to the surface abundance estimate. In general, the tagged loggerheads spent less time at the surface as they moved south in the early autumn. Possible reasons for this trend include:

- a seasonal progression from Aug to Nov
- a latitudinal progression from New Jersey to North Carolina
- changes due to water temperature, either at the surface or sub-surface
- changes due to activities (e.g., feeding versus traveling/migrating)
- changes due to the gender of the individuals
- changes due to particular individuals that happened to have been tagged, and
- changes due to the locations' depth or the depth of the loggerheads' prey.

Further analyses of these data are needed to determine why there was a trend in the percent surface time and if this trend influences the appropriate surface time to be applied to seasonal surface abundance estimates. However, most likely additional telemetry data will have to be collected in future years to fully tease out the explanation for the trend.

Estimates of percent time near the surface were collated in TEWG (2009), but the majority were based on acoustic and radio telemetry data in inshore waters. The three studies that reported information based on satellite telemetry were either for a different region (e.g., Gulf of Mexico) or a different season (autumn). There were no available previous estimates from loggerheads in the continental shelf study area during the summer months where surface was defined as the top 2 m of the water column. There have been two recent studies that provided information on the amount of time the sensor was dry on tagged loggerheads, which would underestimate the amount of time the loggerhead would be available to be sighted. Those estimates for July and August daylight hours ranged from 1.8% off North Carolina (J. Braun-McNeill, personal communication; see Braun-McNeill et al. 2010) to 6.2% in the South Atlantic strata (M. Arendt, personal communication; see Arendt et al. 2009). These values are consistent with our analysis for the South Atlantic stratum.

In conclusion, to provide accurate and precise estimates to account for availability bias, additional analysis are needed of data collected from other studies and this study, and additional data are needed to be collected in the future.

Abundance Estimate Accounting for Perception and Availability Bias

The preliminary abundance estimate presented in the paper is not for the entire population of loggerheads, because the estimate does not include loggerheads that are found outside of the surveyed continental shelf study area, such as south Florida, Gulf of Mexico and Caribbean neritic habitats or the oceanic habitats of the North Atlantic Ocean. Also, loggerheads have been detected at low densities in the North Atlantic stratum during other years in August, the same time period as this study. Thus, this could be interpreted to mean that during the 2010 survey the density of loggerheads in the North Atlantic stratum was not a true zero, but was very low. At the present, the SEFSC is conducting several studies to improve the abundance estimate of loggerheads outside the northwestern Atlantic Ocean continental shelf study area. One study is combining skeletochronology and stable isotope analyses of skeletal growth marks in juvenile loggerheads' humeri to refine estimates of the duration spent in the oceanic stage, the stage outside of the surveyed continental shelf study area. Another study involves tagging juvenile loggerheads on the Grand Banks to determine when they enter the continental shelf study area and to improve the estimates of survival of the juvenile loggerheads. Lastly, in 2011 the SEFSC will begin seasonal surveys of the Gulf of Mexico, from the Mexico/US border to the Florida Keys.

In this study the regional abundance estimate accounting for perception and availability bias was estimated by the product of the surface abundance estimate and percent surface time, as was done in de Segura et al. (2006). There are other ways to account for availability bias, such as that developed in Laake et al. (1997) and, for example, as applied by Forcada et al. (2004) to bottlenose dolphins. The Laake method is based on a probabilistic model of an alternating renewal process for animals that are intermittently available, as is true for aerial surveys. The model explicitly accounts for speed of the plane, time between the detection of groups that were seen by both teams, the region around the plane animals can be detected within, and the average surface and dive times. This method is particularly beneficial when applied to the circle-back data where the time between detection of duplicate sightings can explicitly be accounted for.

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APPENDIX 1. THE CIRCLE-BACK PROCEDURE

The criterion that started a circle-back was a single small group (≤ 5 animals) of cetaceans or turtles that were seen within a 30 second time period. The detailed circle-back procedure was as follows (Figure A1):

1. Time and location of an initial sighting when it passed abeam of the plane was marked and started a 30-second timer,
2. During the 30-seconds, additional sightings were recorded as usual. If more than one additional sighting of the same species that triggered the circle were recorded during this time, then the circle-back procedure was aborted (because the density may be too high to accurately determine if a group of animals was the same group on both the leading and trailing legs of the track line).
3. At the end of the 30-seconds, if the criterion in number 2 was passed, the plane started to circle back and the observers went off effort. The time leaving the track line was marked, which started another timer for 120 seconds.
4. During this 120 seconds the plane circled back 180º and traveled parallel to the original track line about 0.8 nmi away, in the opposite direction, and on either side of the original track line.
5. At the end of the 120 seconds, the plane started to fly back to the track line.
6. When the plane intercepted the original track line, the time was marked, observers went back on effort, started searching again, and a 5-minute timer was started.
7. Sightings were then recorded as usual.
8. The circle-back procedure was not initiated again until a sighting was made after the 5-minute timer had expired. This was to insure forward progress on the track line.

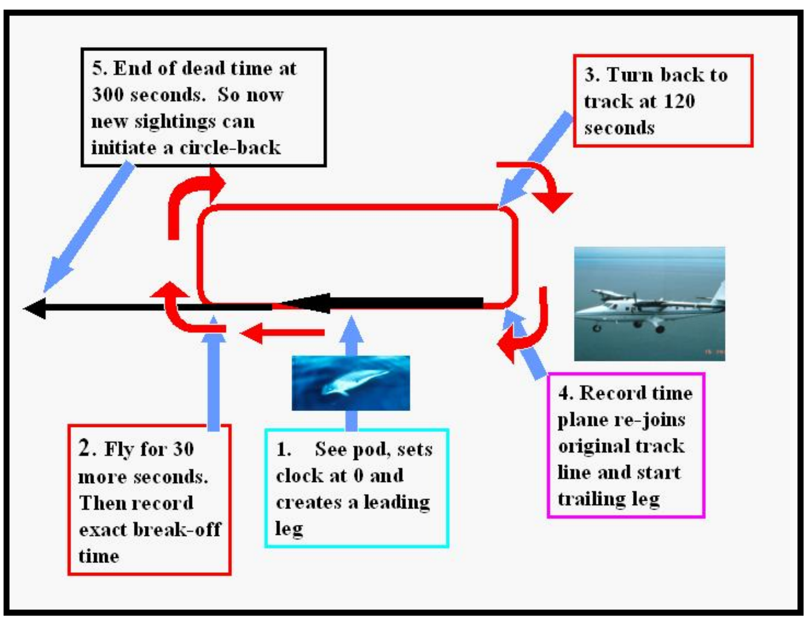

Figure A1. Diagram of how the circle-back technique was performed.

Table 1. General description of each stratum: including the area (in km^2), length of track lines (in km) and dates flown during the aerial survey.

Stratum	General description	Area (km^2)	Track length (km)	Dates flown
South Atlantic	Cape Canaveral, FL to Cape Hatteras, NC	104,580	5002.9	24 Jul – 4 Aug
Mid-Atlantic South	Cape Hatteras, NC to NJ	62,104	2931.7	7–11 Aug
Mid-Atlantic North	NJ to MA	73,180	1922.9	17-19Aug, 6 Sep
North Atlantic	MA to Gulf of St. Lawrence, Canada	251,777	7284.1	19 Aug – 26 Sep
TOTAL	Cape Canaveral, FL to Gulf of St. Lawrence, Canada	491,641	17,142	24 Jul – 26 Sep

Table 2. Number of turtle groups detected during the aerial surveys, by stratum.

Turtle species		Number of groups detected				
		South Atlantic	Mid-Atlantic South	Mid-Atlantic North	North Atlantic	TOTAL
Loggerhead	*Caretta caretta*	381	183	34	0	598
Green	*Chelonia mydas*	18	89	9	0	116
Kemp's ridley	*Lepidochelys kempii*	14	5	7	0	26
Unid hardshell	Chelonioidea	225	225	7	0	457
Leatherback	*Dermochelys coriacea*	57	37	5	14	113
TOTAL		695	539	62	14	1310

Table 3. Intermediate components used to estimate the surface abundance accounting for perception bias, *g(0)*, of only positively identified loggerheads (*Caretta caretta*) and only unidentified turtles in the Mid-Atlantic North and North Atlantic strata. Table 3A. Number of sightings after truncation (n_t) where the truncation distance was 450 m, average group size (avg gs), effective strip width (ESW, in m), $g(0)_{leading}$, surface density (individuals/km^2) and abundance, when *g(0)*=1 and when *g(0)*<1, along with the associated coefficient of variations (CV) of each component. Note, not all unidentified turtles are loggerheads. Table 3B. Using data from the leading and trailing legs, estimated values of $g(0)_{leading \cdot L}$ and its components: number of sightings (n) and ESWs of the duplicate and trailing sightings.

Table 3A.

Intermediate Component	Mid-Atlantic North: Only loggerheads	Mid-Atlantic North: Only unidentified turtles*	North Atlantic: Only loggerheads
n_t	30	7	0
CV(n_t)	0.39	0.44	0
ESW (in m)	210	210	0
CV(ESW)	0.15	0.15	0
avg gs	1.0	1.0	0
CV(avg gs)	0.00	0.00	0
Surface density, *g(0)*=1 (individuals/km^2)	0.0371	0.0087	0
Surface abundance, *g(0)*=1	2,711	634	0
CV(surface abun, *g(0)*=1)	0.4210	0.4669	0
$g(0)_{leading}$	0.70	0.70	0
CV($g0_{leading}$)	0.35	0.35	0
Surface density, *g(0)*<1 (individuals/km^2)	0.0529	0.0124	0
Surface abundance, *g(0)*<1	**3,873**	**906**	**0**
CV(surface abun, *g(0)*<1)	0.5445	0.5812	0

*Not all unidentified turtles are loggerheads.

Table 3B.

Duplicate sightings: n	Duplicate sightings: ESW	Duplicate sightings: CV(ESW)	Trailing sightings: n	Trailing sightings: ESW	Trailing sightings: CV(ESW)	$g(0)_{leading}$	CV[$g(0)_{leading}$]
47	229.4	0.1252	73	249.4	0.1554	0.70	0.3453

Table 4. Intermediate components used to estimate the surface abundance accounting for perception bias of only positively identified loggerheads (*Caretta caretta*) and only unidentified hardshell turtles in the Mid-Atlantic South and South Atlantic strata. Number of sightings after truncation (n_t) where the truncation distance was 300 m, average group size (avg gs), effective strip width (ESW, in m), surface density (individuals/km^2) and abundance, when *g(0)*<1, along with the associated coefficient of variations (CV) of each component. Note, not all unidentified hardshell turtles are loggerheads.

Intermediate component	South Atlantic		Mid-Atlantic South	
	Only loggerheads	Only unidentified hardshell turtles*	Only loggerheads	Only unidentified hardshell turtles*
n_t	374	212	181	217
Average ESW (in m)	134	172	134	172
CV (avg ESW)	0.052	0.087	0.052	0.087
Avg sighting probability	0.447	0.573	0.447	0.573
Avg gs	1.328	1.13	1.229	1.22
CV(avg gs)	0.0422	0.0283	0.0480	0.0336
Surface density, *g(0)*<1 (individuals/km^2)	0.3273	0.1417	0.2798	0.2637
Surface abundance, *g(0)*<1	**38,974**	**14,825**	**17,376**	**16,379**
CV(surface abund, *g(0)*<1)	0.1644	0.1930	0.1969	0.1920

*Not all unidentified turtles are loggerheads.

Table 5. For each strata, preliminary estimates of the surface abundance, accounting for perception bias (*g(0)*<1) when using positively identified loggerheads (*Caretta caretta*) and a portion of the unidentified turtles, along with the intermediate calculations and the associated coefficient of variations (CV; in parentheses).

	Surface abundance estimate, *g(0)*<1 (CV)			
Strata	Only positively identified loggerheads	Only unidentified turtles	% loggerheads of the unidentified turtles	Positively identified loggerheads + portion of unidentified turtles
South Atlantic	38,974 (0.164)	14,825 (0.193)	0.9225	52,650 (0.133)
Mid-Atlantic South	17,376 (0.197)	16,379 (0.192)	0.6606	28,196 (0.165)
Mid-Atlantic North	3,873 (0.544)	906 (0.581)	0.6800	4,489 (0.484)
North Atlantic	0	0	0	0
TOTAL	60,223 (0.126)			85,335 (0.102)

Table 6. For loggerheads (*Caretta caretta*) tagged in the Mid-Atlantic South stratum, release dates, locations and sizes of animals as defined by the curved carapace length (CCL) and straight carapace length (SCL), in cm. The SCL is based on measured standard CCL converted to standard SCL using $SCL_{std} = CCL_{std} * 0.9264$ (TEWG 2009).

Date	Latitude	Longitude	SCL (cm)	CCL (cm)
08/04/10	39.80	73.06	68.6	74
08/05/10	38.86	73.72	72.7	79
08/06/10	38.90	73.70	56.5	61
08/06/10	38.94	73.64	65.8	71
08/06/10	38.89	73.70	79.7	86
08/07/10	38.68	74.09	78.7	85
08/09/10	38.75	73.87	70.4	76
09/09/10	38.70	73.06	68.6	74
09/10/10	38.76	73.83	74.1	80
09/10/10	38.76	73.82	80.6	87
09/11/10	38.64	74.12	62.1	67
09/11/10	38.66	74.09	65.8	71
09/11/10	38.69	73.96	74.1	80
09/11/10	38.64	74.12	89.9	97

Table 7. For loggerheads (*Caretta caretta*) tagged in the South Atlantic stratum, release dates, locations and sizes of animals as defined by the curved carapace length (CCL) and straight carapace length (SCL), in cm. The CCL was based on measured standard SCL converted to standard CCL using $CCL_{std} = SCL_{std}/0.9264$ (TEWG 2009).

Date	Latitude	Longitude	SCL (cm)	CCL (cm)
7/13/2010	30.56	-81.4	62.7	67.7
5/24/2010	30.72	-79.76	72.4	78.2
6/14/2010	31.52	-81.15	58.1	62.7
6/14/2010	31.32	-81.15	70.5	76.1
6/22/2010	30.53	-81.42	77.1	83.2
6/17/2010	32.05	-80.69	78.4	84.6
6/7/2010	32.75	-79.71	60.9	65.7
5/27/2010	32.9	-79.49	76.4	82.5
6/30/2010	32.00	-80.76	69.7	75.2
6/10/2010	30.53	-81.38	75.4	81.4
6/14/2010	31.32	-81.15	72.6	78.4
6/17/2010	31.18	-81.11	79.6	85.9
6/8/2010	32.74	-79.7	65.9	71.1
7/9/2010	31.11	-81.28	58.3	62.9
6/22/2010	30.53	-81.42	63.7	68.8
7/8/2010	31.31	-81.15	71.4	77.1
6/8/2010	32.8	-79.57	76.1	82.1
6/22/2010	30.53	-81.42	72.7	78.5
7/12/2010	30.67	-81.36	66.6	71.9
6/2/2010	31.95	-80.72	79.8	86.1
6/15/2010	31.33	-81.13	73.7	79.6
6/16/2010	32.05	-80.74	73.8	79.7
6/24/2010	30.7	-81.43	75.4	81.4
6/24/2010	30.73	-81.42	70.8	76.4
6/15/2010	31.24	-81.11	74.7	80.6
7/7/2010	31.18	-81.21	68.9	74.4
6/10/2010	30.53	-81.36	66.2	71.5
6/9/2010	32.73	-79.65	66.9	72.2
7/14/2010	30.61	-81.43	66.7	72.0
6/3/2010	32.27	-80.41	76.5	82.6

Table 8. Preliminary estimated regional abundance of only positively identified loggerheads (*Caretta caretta*) within the northwest Atlantic continental shelf study area when accounting for perception bias (*g(0)*<1) and availability bias (% surface time) – termed adjusted abundance, with associated inner quartile range.

Strata	Abundance positively identified loggerheads, *g(0)*<1	Median %surface time	1st Quartile %surface time	3rd Quartile %surface time	Adjusted positively identified loggerheads abundance	Lower quartile range of adjusted positively identified loggerheads abundance	Upper quartile range of adjusted positively identified loggerheads abundance
South Atlantic	38,974	7.0	5.0	11.0	556,771	354,309	779,480
Mid-Atlantic South	17,376	67.1	56.6	76.9	25,896	22,596	30,700
Mid-Atlantic North	3,873	67.1	56.6	76.9	5,772	5,036	6,843
North Atlantic	0	67.1	56.6	76.9	0	0	0
TOTAL	60,223				588,439	381,941	817,023

Table 9. Preliminary estimated regional abundance of positively identified loggerheads (*Caretta caretta*) and a portion of the unidentified turtles (loggerheads+) within the northwest Atlantic continental shelf study area when accounting for perception bias (*g(0)*<1) and availability bias (% surface time) – termed adjusted abundance, with associated inner quartile range.

Strata	Abundance loggerheads+, *g(0)*<1	Median %surface time	1st Quartile %surface time	3rd Quartile %surface time	Adjusted loggerheads+ abundance	Lower quartile range of adjusted loggerheads+ abundance	Upper quartile range of adjusted loggerheads+ abundance
South Atlantic	52,650	7.0	5.0	11.0	752,143	478,636	1,053,000
Mid-Atlantic South	28,196	67.1	56.6	76.9	42,021	36,666	49,816
Mid-Atlantic North	4,489	67.1	56.6	76.9	6,690	5,837	7,931
North Atlantic	0	67.1	56.6	76.9	0	0	0
TOTAL	85,335				800,854	521,139	1,110,747

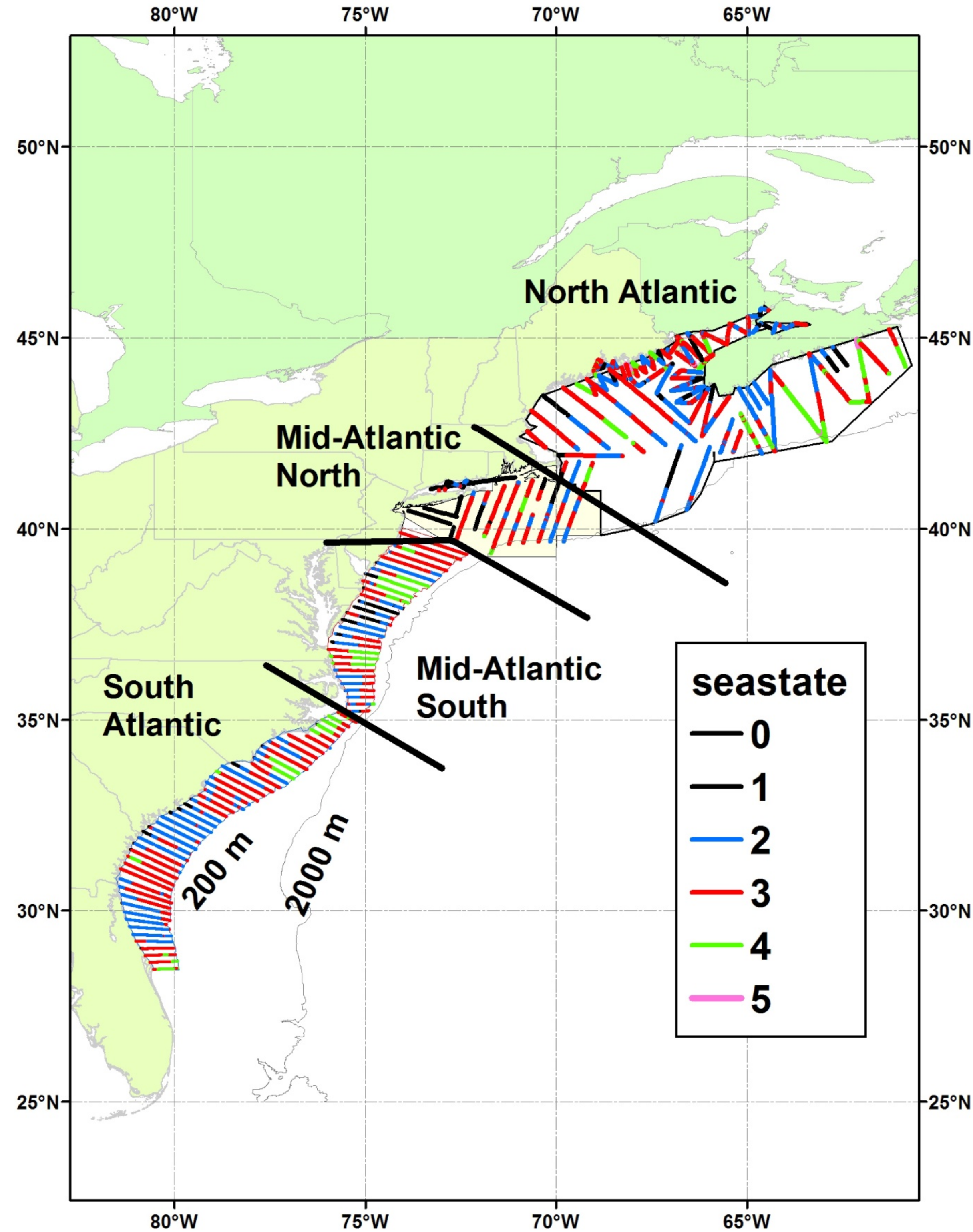

Figure 1. Location of the northwestern Atlantic continental shelf study area, strata, and track lines surveyed during the aerial abundance survey, 24 Jul – 26 Sep 2010.

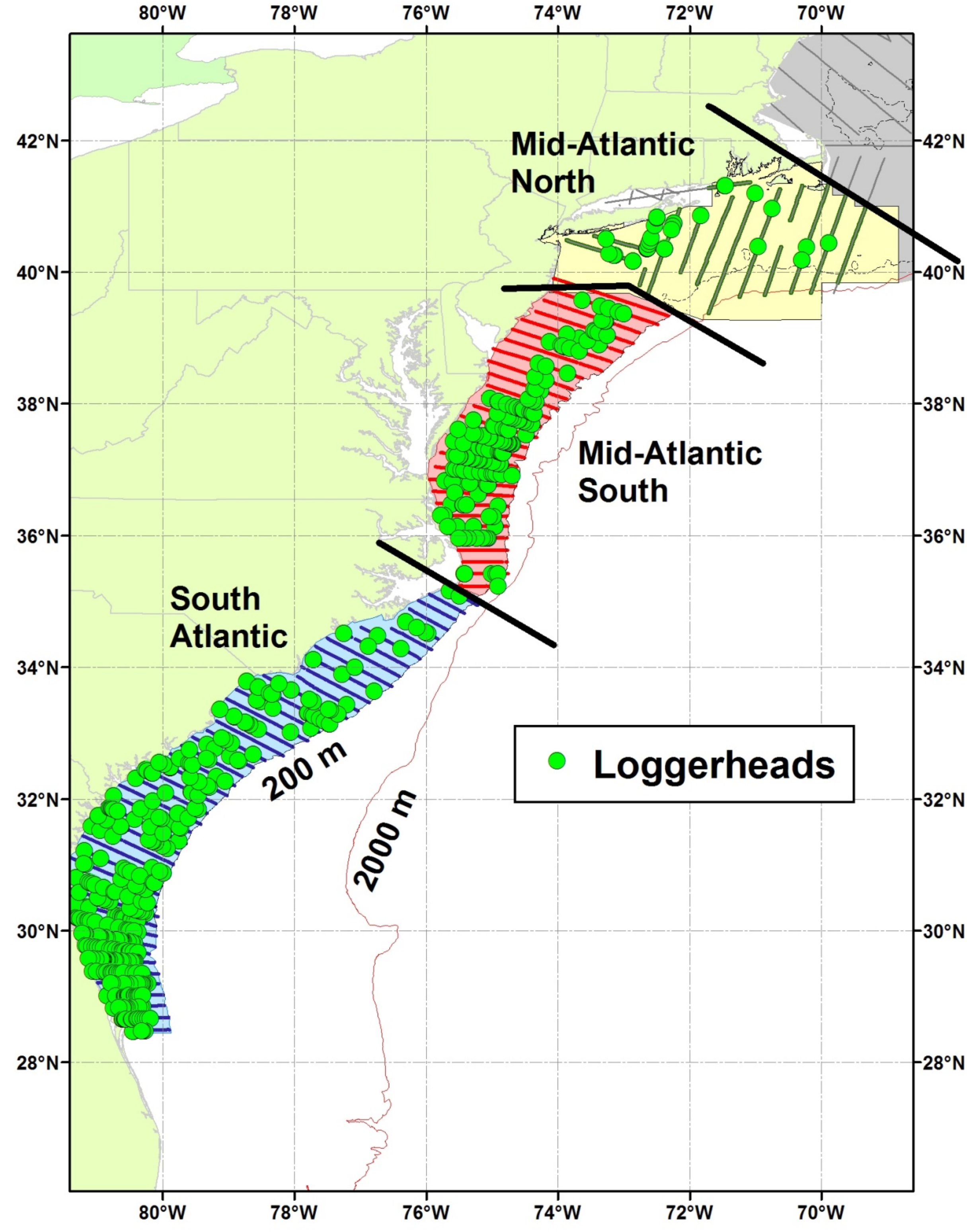

Figure 2. Location of loggerhead (*Caretta caretta*) groups detected in the aerial survey.

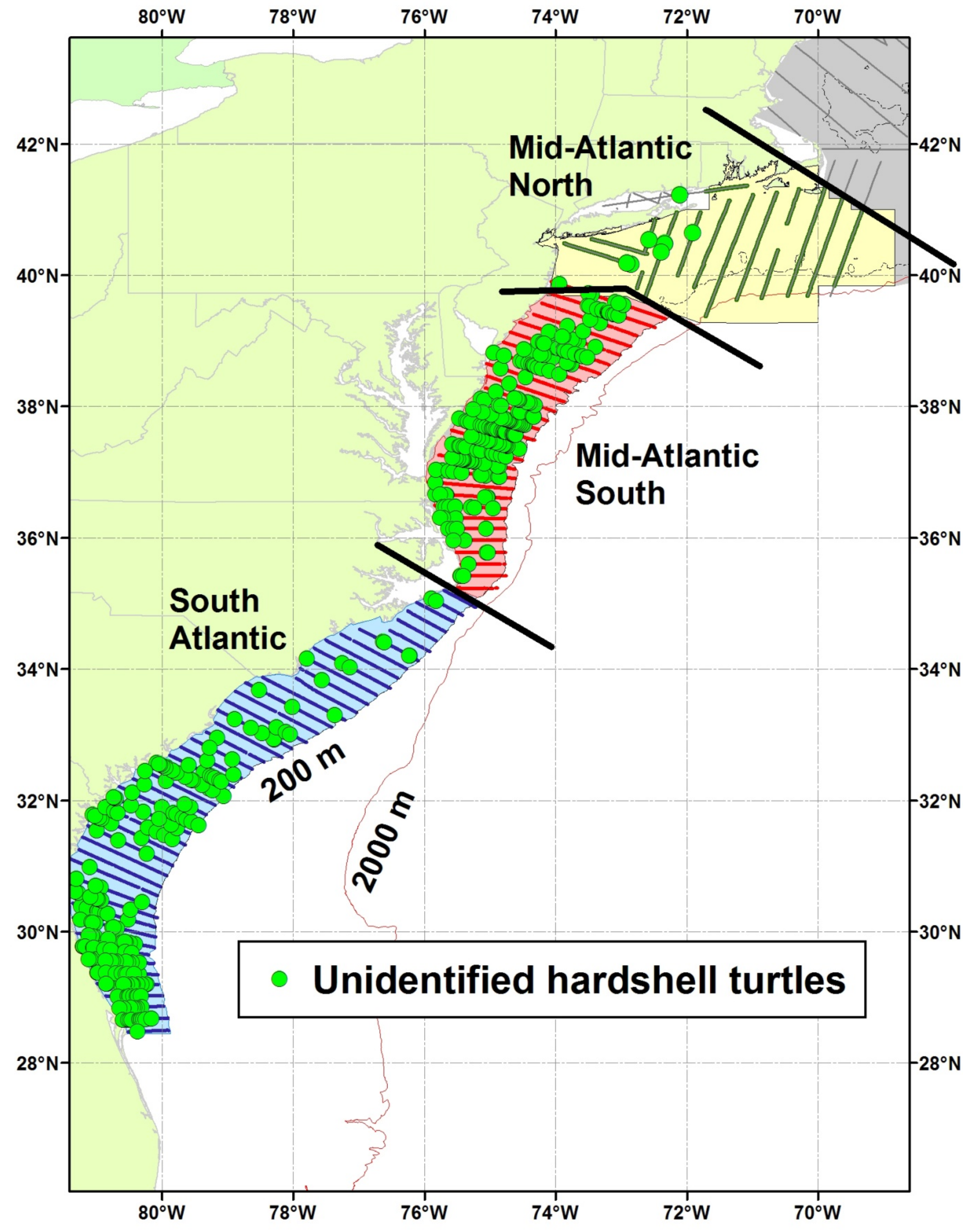

Figure 3. Location of unidentified hardshell turtle groups detected in the aerial survey.

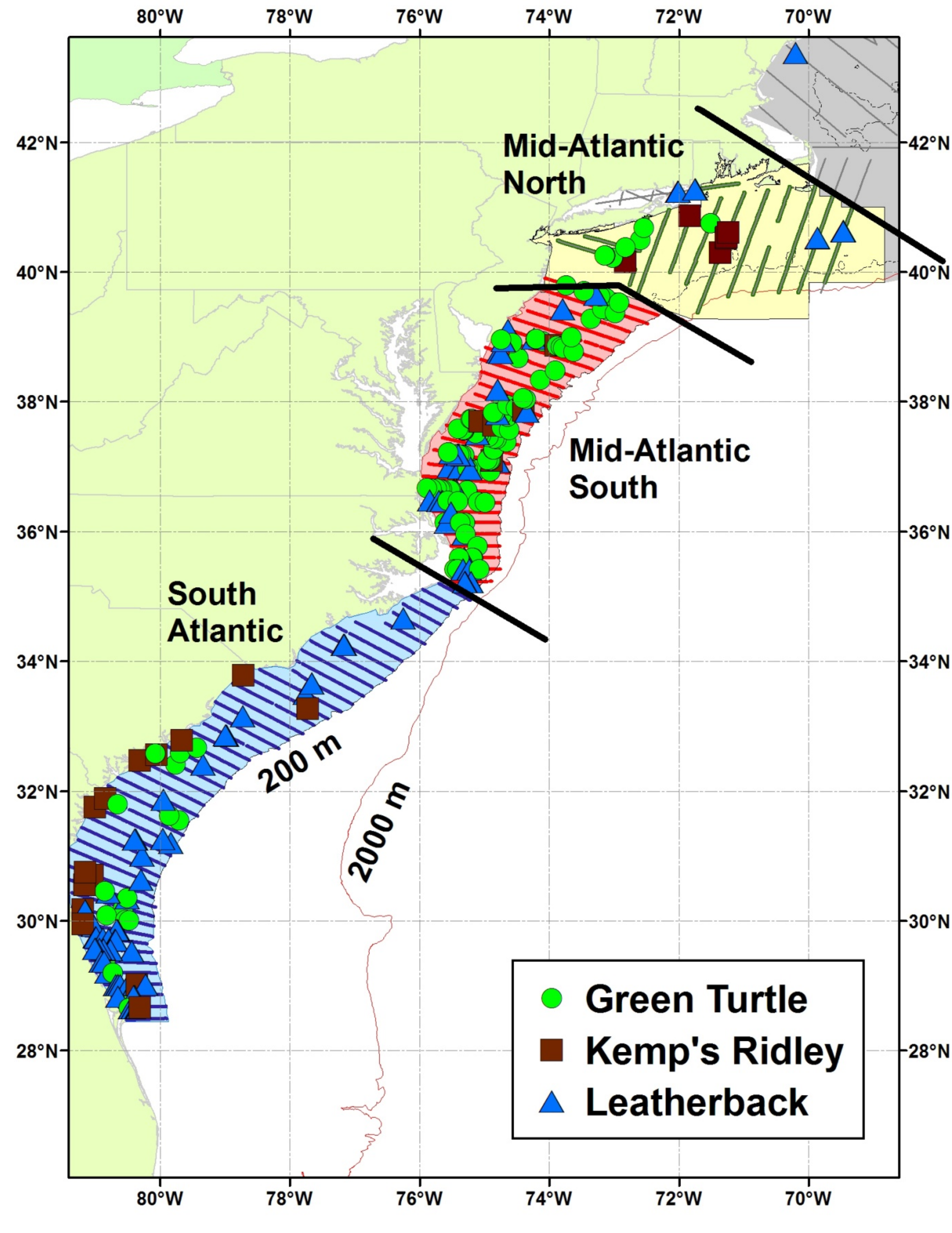

Figure 4. Location of green turtle (*Chelonia mydas*), Kemp's Ridley turtle (*Lepidochelys kempii*) and leatherback turtle (*Dermochelys coriacea*) groups detected in the aerial survey.

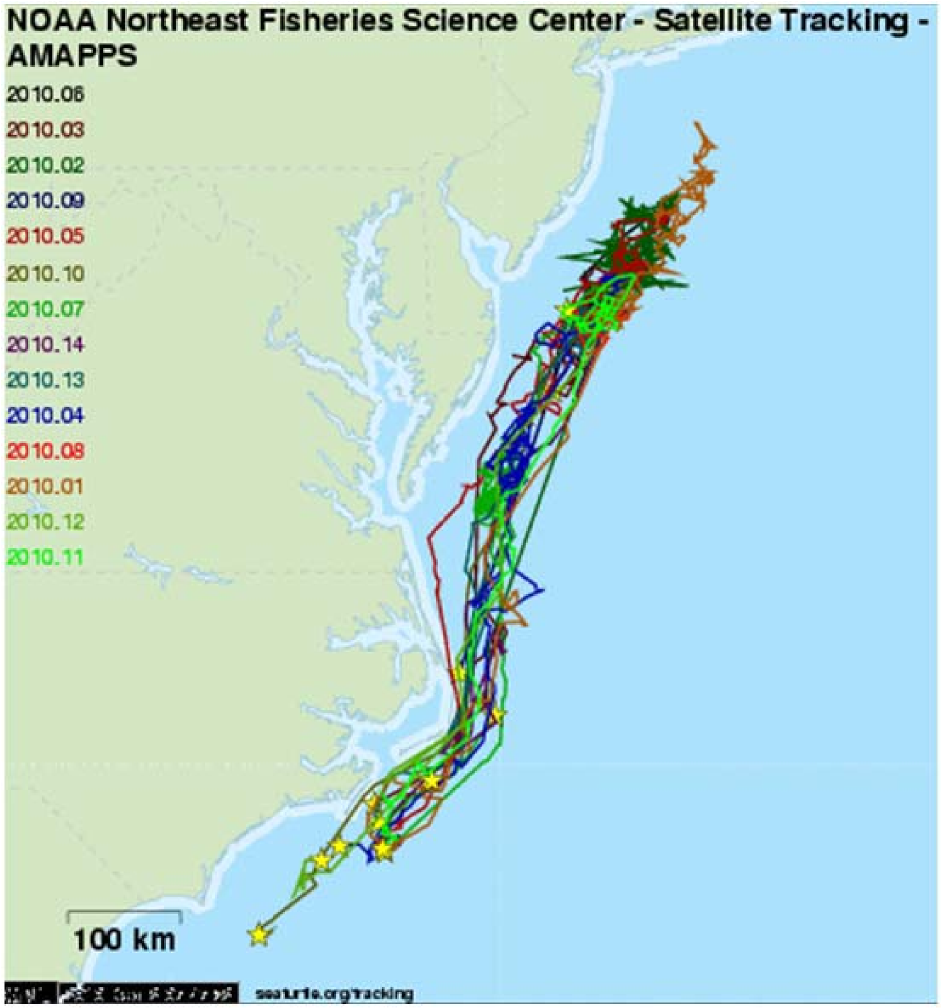

Figure 5. Location and track data from 14 northern juvenile loggerheads (*Caretta caretta*) tagged off New Jersey and Delaware, as displayed by www.seaturtle.org on 1 Dec 2010. Stars indicate last recorded location.

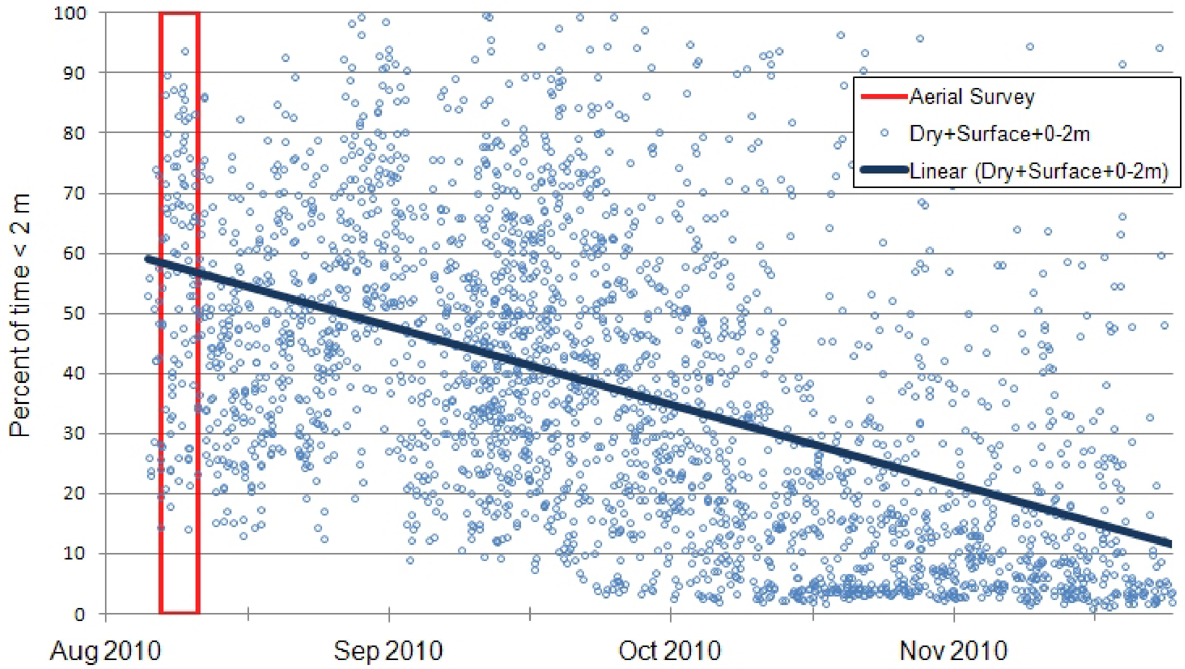

Figure 6. Percent surface time (percent time < 2 m) of northern tagged loggerheads (*Caretta caretta*). Each circle represents a 6-hr summary from a single loggerhead. Times when the survey was flying in the Mid-Atlantic South stratum is shown in the red box. A simple linear regression between date and percent of time < 2 m is shown with the dark blue line.

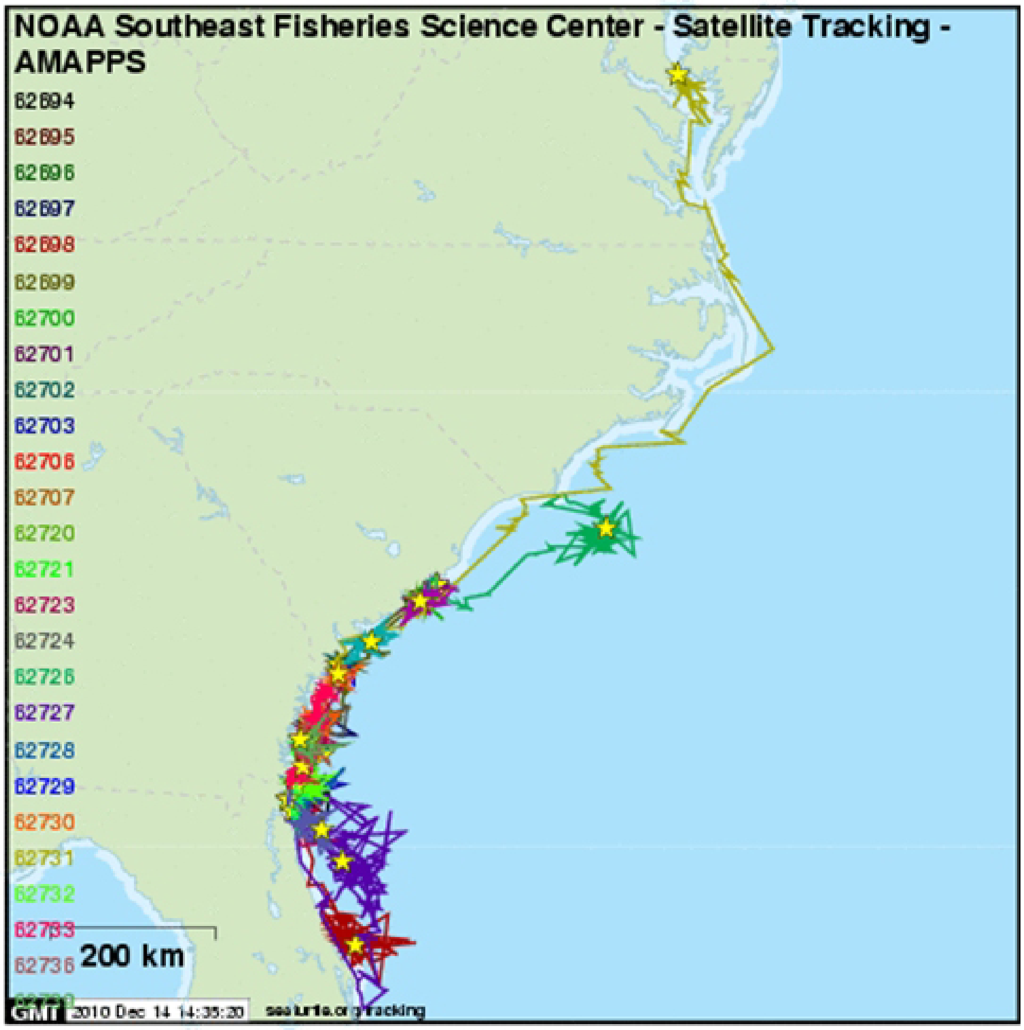

Figure 7. Location and track data from 30 southern juvenile loggerheads (*Caretta caretta*) tagged off northern Florida to South Carolina, as displayed by www.seaturtle.org on 13 Dec 2010. Stars indicate last recorded location.

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